

Diffusion in Si Oxynitride Gate Dielectrics

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Introduction: Measurements such as ellipsometry or x-ray reflectivity of oxynitride gate dielectric materials <5 nm thick have problems determining the thickness and composition of the layer or layers. The optical constants of the layers need to be inferred or determined by other means. Grazing incidence XPS using synchrotron radiation is a method of obtaining both the thickness and the chemical composition of the layers. The nonlinear behavior of x-ray fields in layers with different optical constants and the decreasing penetration within the critical angle permit us to separate the components of the XPS spectra by layer.

Methods and Materials: Ultra-thin gate dielectric materials fabricated on Si for CMOS logic were investigated using grazing incidence x-ray photoelectron spectroscopy (GIXPS). Si wafers were oxidized using remote plasma-assisted oxidation, then given a nitride layer using remote plasma-assisted chemical vapor deposition. The layers were typically less than 5 nm thick. The GIXPS method was then used to determine the diffusion and ordering of the components after different anneals, for example rapid thermal annealing or atmospheric furnace anneal in water vapor. X-ray photoemission spectra were taken at an energy of 1820 eV over a series of incidence angles around the critical angle for total external reflection from Si ($\phi \approx 0.7^\circ$).

Results: We observe that under most conditions, the nitrogen diffuses to the Si bulk interface. Under certain conditions, a nitride layer appears to form above the oxide-rich component.

Conclusions: The formation of this layer coincides with confusing results obtained from ellipsometry and x-ray reflectometry measurements.

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